Initial Characterization of Occupant Exposure during a Generic Underbelly Blast Event

Stephen Bernstein, MD, MPH
COL, MC, MFS
Injury Biomechanics Branch, WPD
USAARL

Michael Tegtmeyer
Warfighter Survivability Branch
Survivability/Lethality Analysis Directorate
Army Research Lab

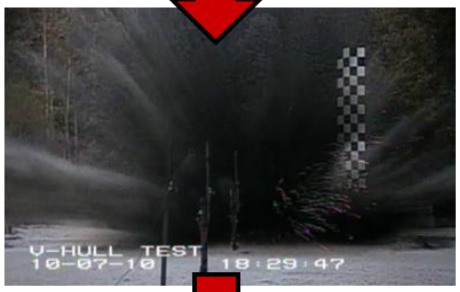
TARDEC
Risa Scherer
Chris Felczak

ARL/SLAD
Patricia Frounfelker

USAARL
Fred Brozoski
Katie Logsdon
Kim Vasquez
Joe McEntire
Carol Chancey

What is the problem?

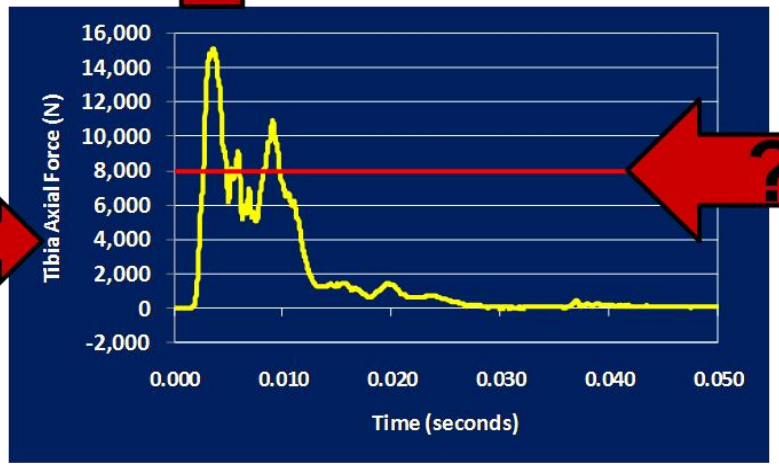
• Current live-fire test and evaluation measurement devices and analysis methodologies do not yield accurate prediction of injury during Under Body Blast Test events. . .



Operational

Unable to assess the effects when LFT&E data greatly exceed automotive injury criteria

?



?

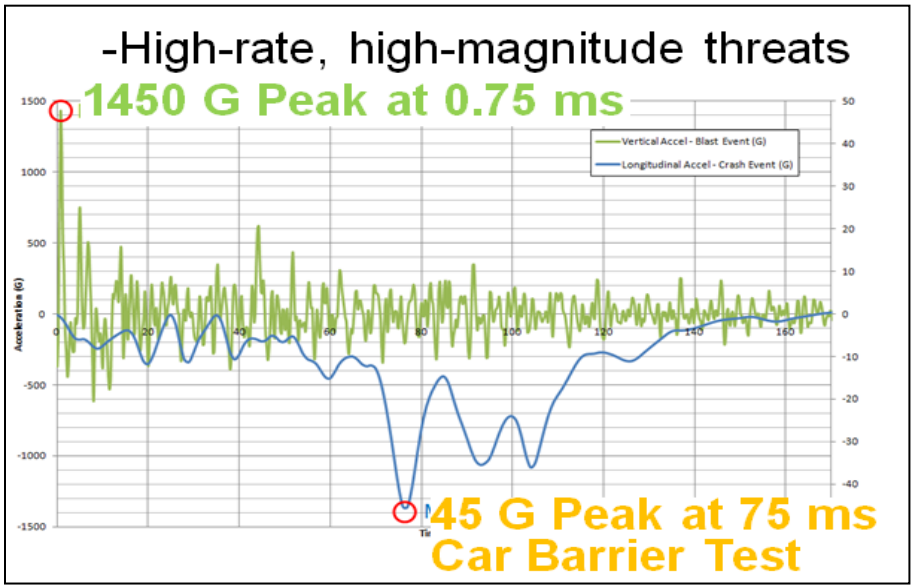
Automotive

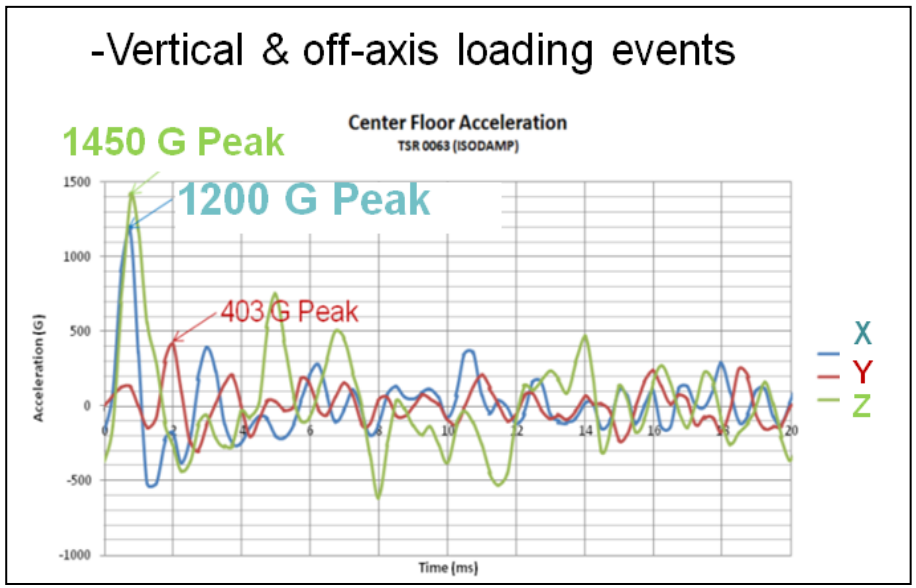
Distal Tibia Fx

CAUSATIVE MECHANISMS OF INJURY ARE POORLY UNDERSTOOD

What is the problem?

- Lack of biofidelic human injury response data for Under Body Blast Test events . . .





- Unknown effects of military environment, e.g. posture, combat load, seat orientation . . .

COMPLEX MILITARY OPERATIONAL ENVIRONMENT NOT REPRESENTED BY CIVILIAN-BASED DEVICES/STANDARDS

Underbelly Blast Test Event (October 2010): USAARL, TARDEC, & ARL/SLAD Generic Hull Testing

- Due to data classification (CLASSIFIED or PROPRIETARY), it is difficult to educate industry and academia on the severity, speed, and loads of underbody blast events

- The JAIWG team conducted a “Generic Hull” blast test to collect releasable data (hull response, occupant response loads, video, etc.) for public release

- Generic Hull Characteristics:
  - V-Hull
  - Two forward facing seats (driver and commander) mounted to underbody support ribs
  - Four inward facing crew seats mounted to hull walls
  - Hull floor mounted to ribs which were connected to V-hull
  - Completely sealed windows, doors and back hatch

Generic Hull:
Instrumentation and Data Acquisition Systems

To characterize occupant exposures,

1) Various instrumented ATDs were occupants in the Hull to measure loading rates and magnitudes
2) Vehicle structural responses (Seat, Floor) were measured using several accelerometers packages, including two from which data will be presented:

● Seat Pan Single Axis (2K g) ● Floor mounted Triax (60K g)

Generic Hull:
Instrumentation and Data Acquisition Systems

The vehicle data were recorded using several Data Acquisition Systems recording at a variety of sampling rates (1 ksps - 1 Msps)

Video footage recorded using:

- Motion capture camera system (200 fps)
- High speed cameras (1,000 and 2,000 fps)
- Standard video camera (30 fps)

Generic Hull: Test Setup

Driver position

Crew Compartment

Test Videos

Generic Hull: Post Test Pictures

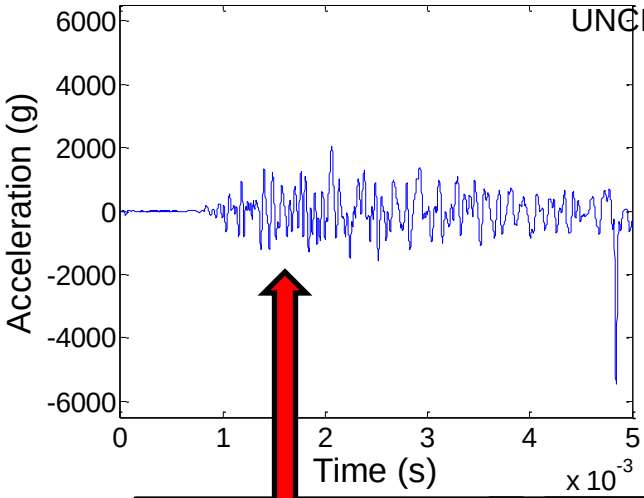
Driver seat attachment failure, forward flail

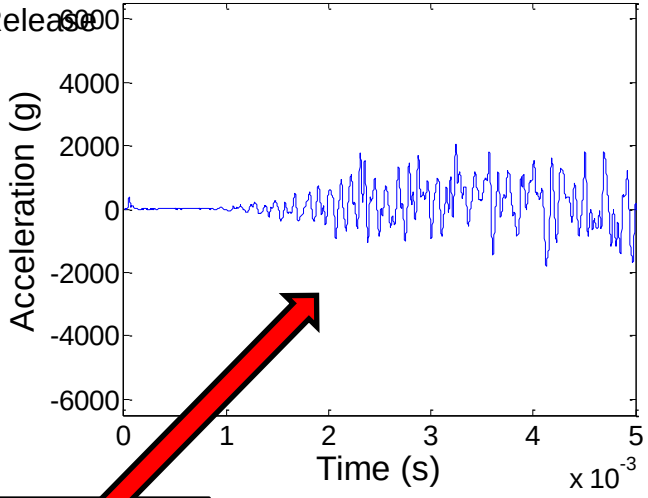
Commander's seat attachment failure, rearward flail

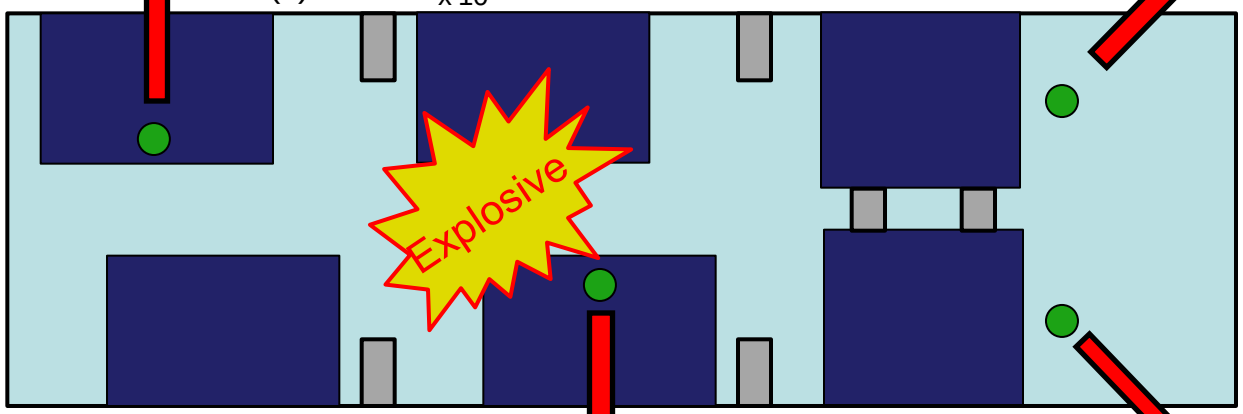
Generic Hull: Post Test Pictures

Post-test crew compartment, note foot entrapment

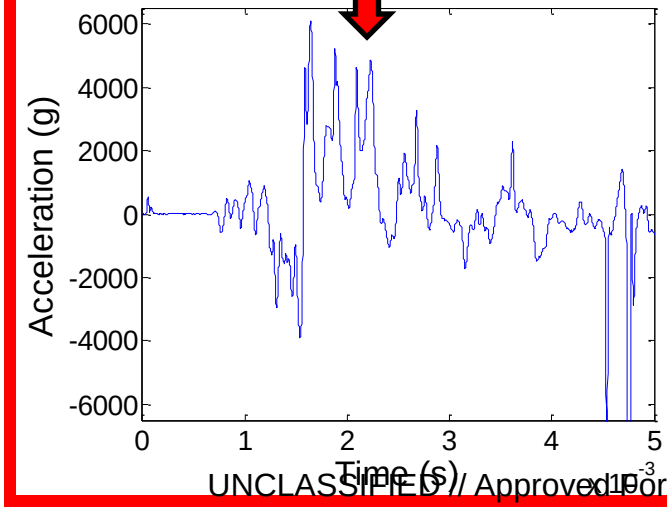
Structural Responses through the Vehicle

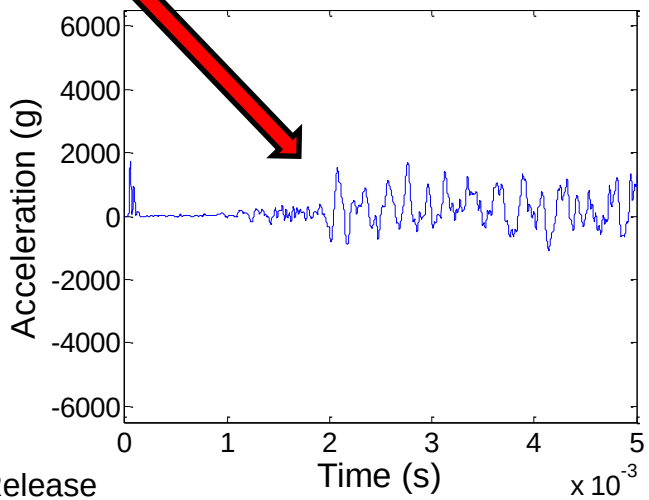




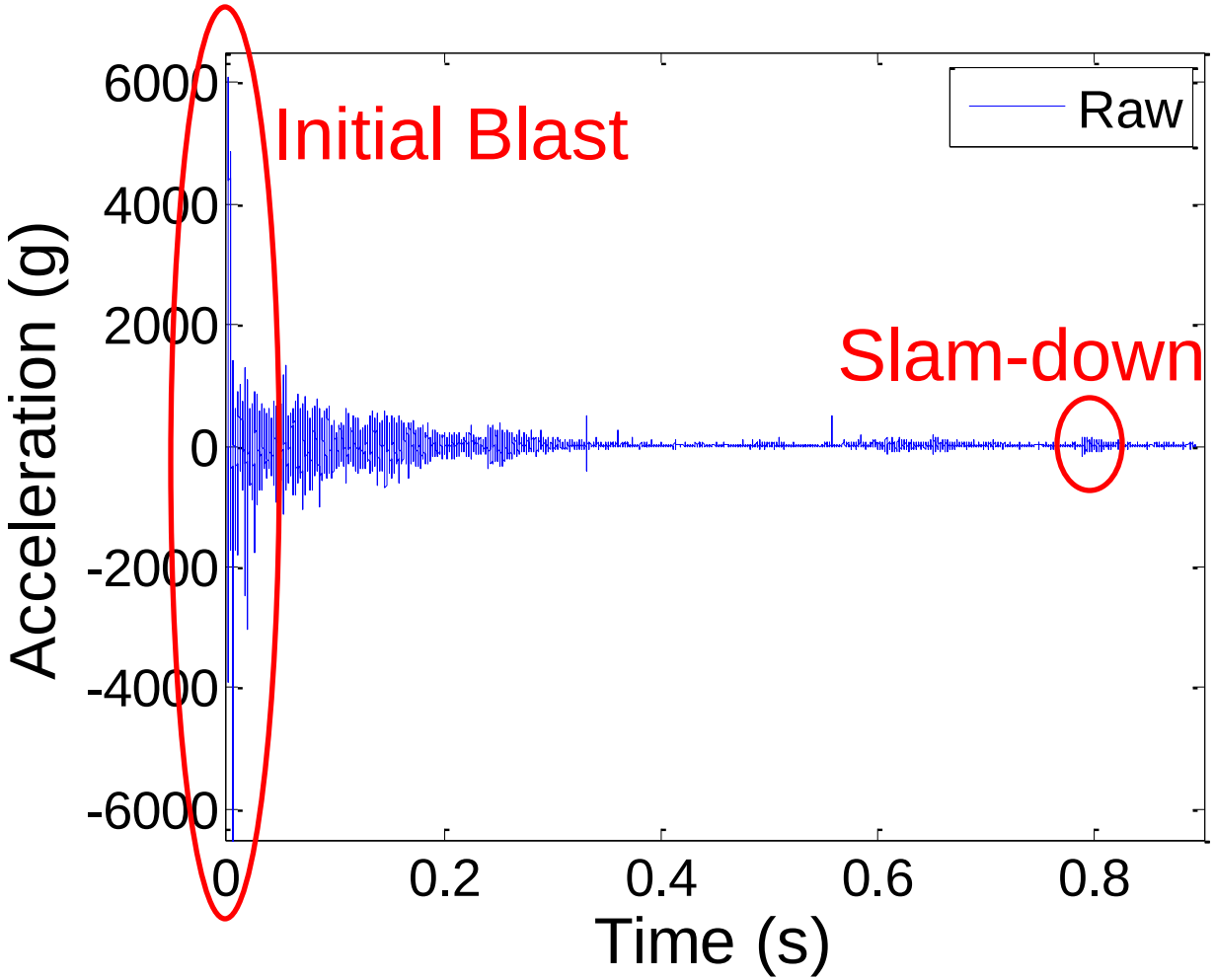


Vertical floor accelerations vary by sensor position relative to charge



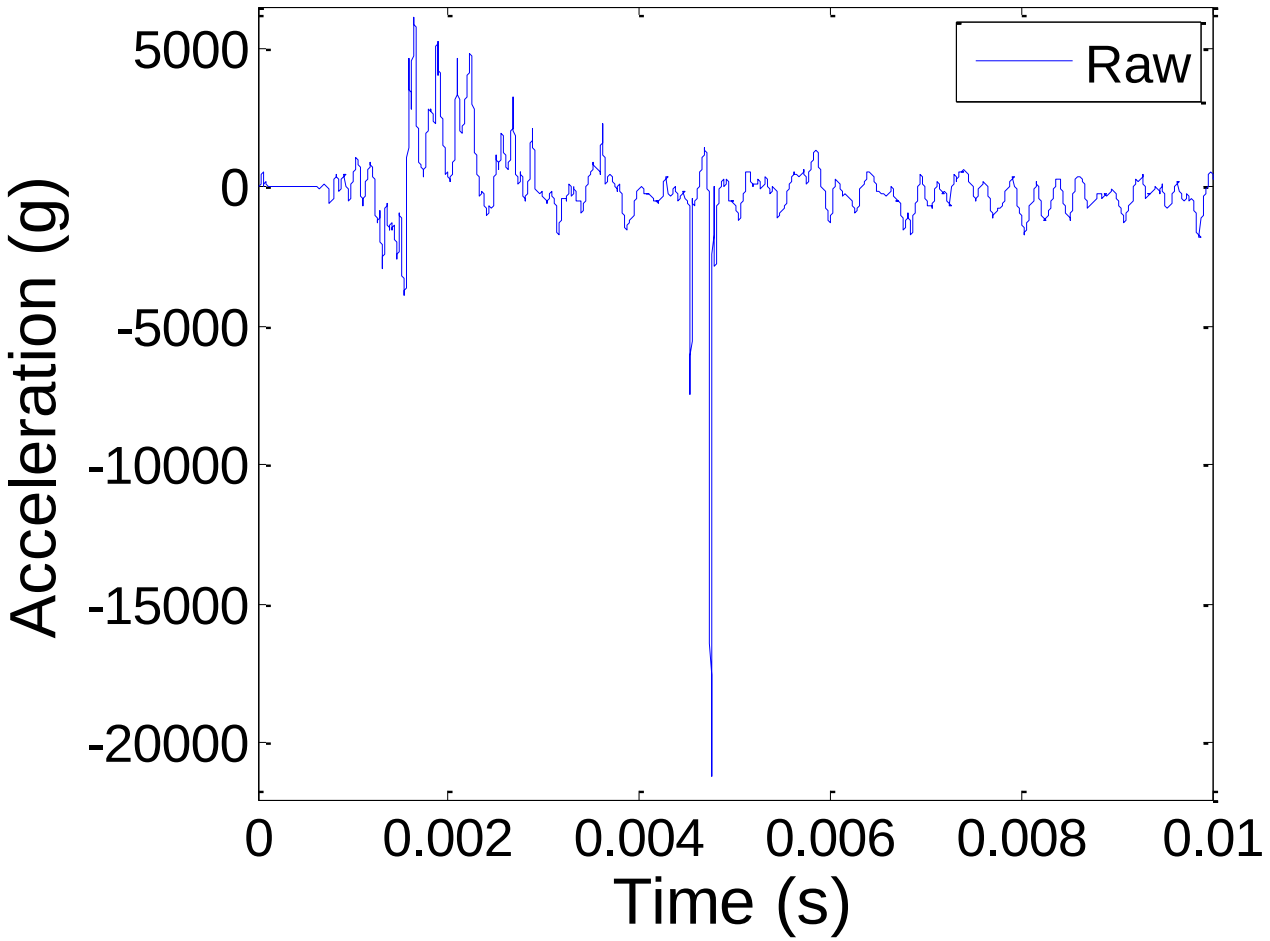


Floor Vertical Acceleration Traces



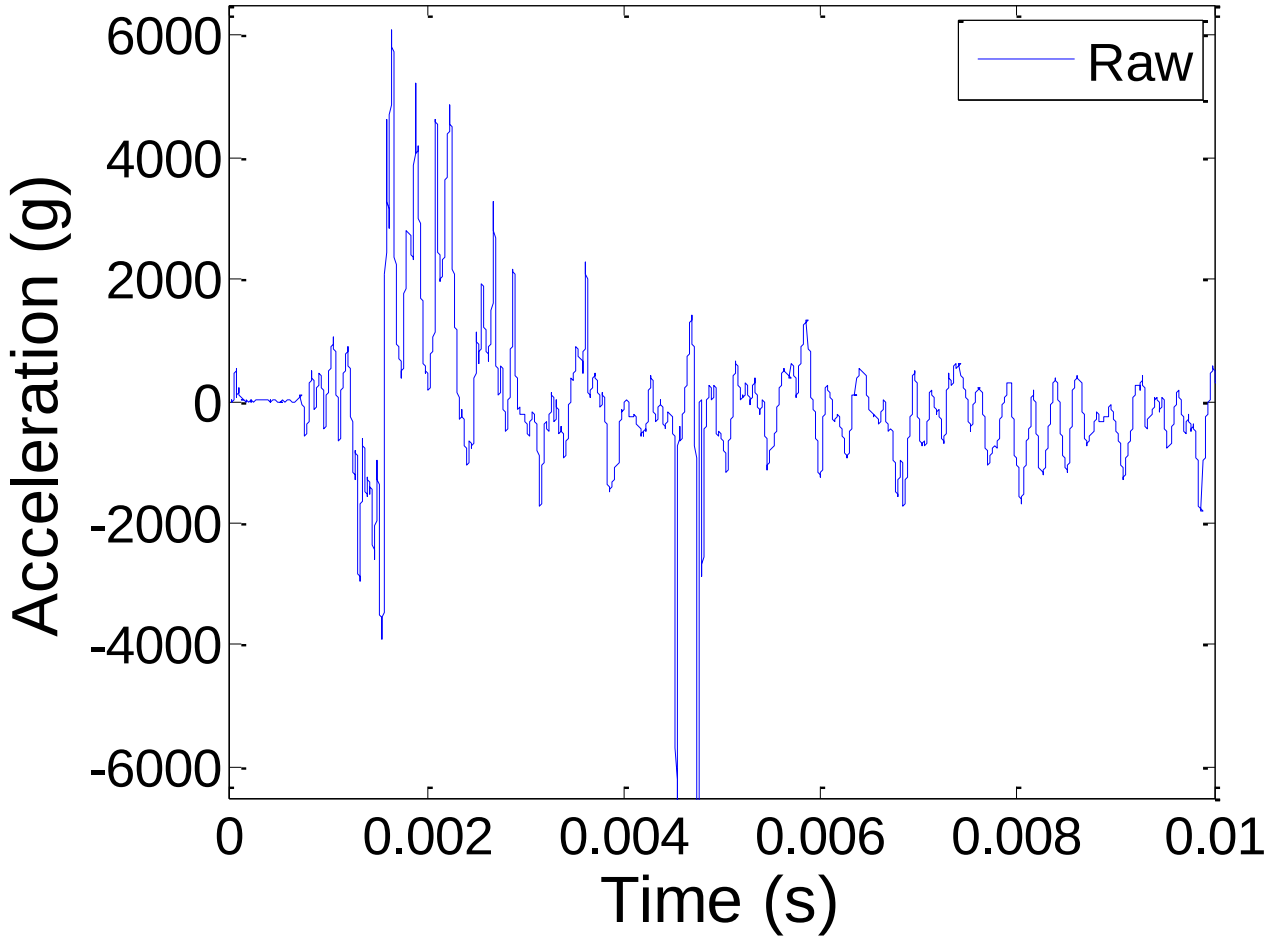
There are distinct sub-events that can be recognized (and corroborated through video)

Floor Vertical Acceleration Traces



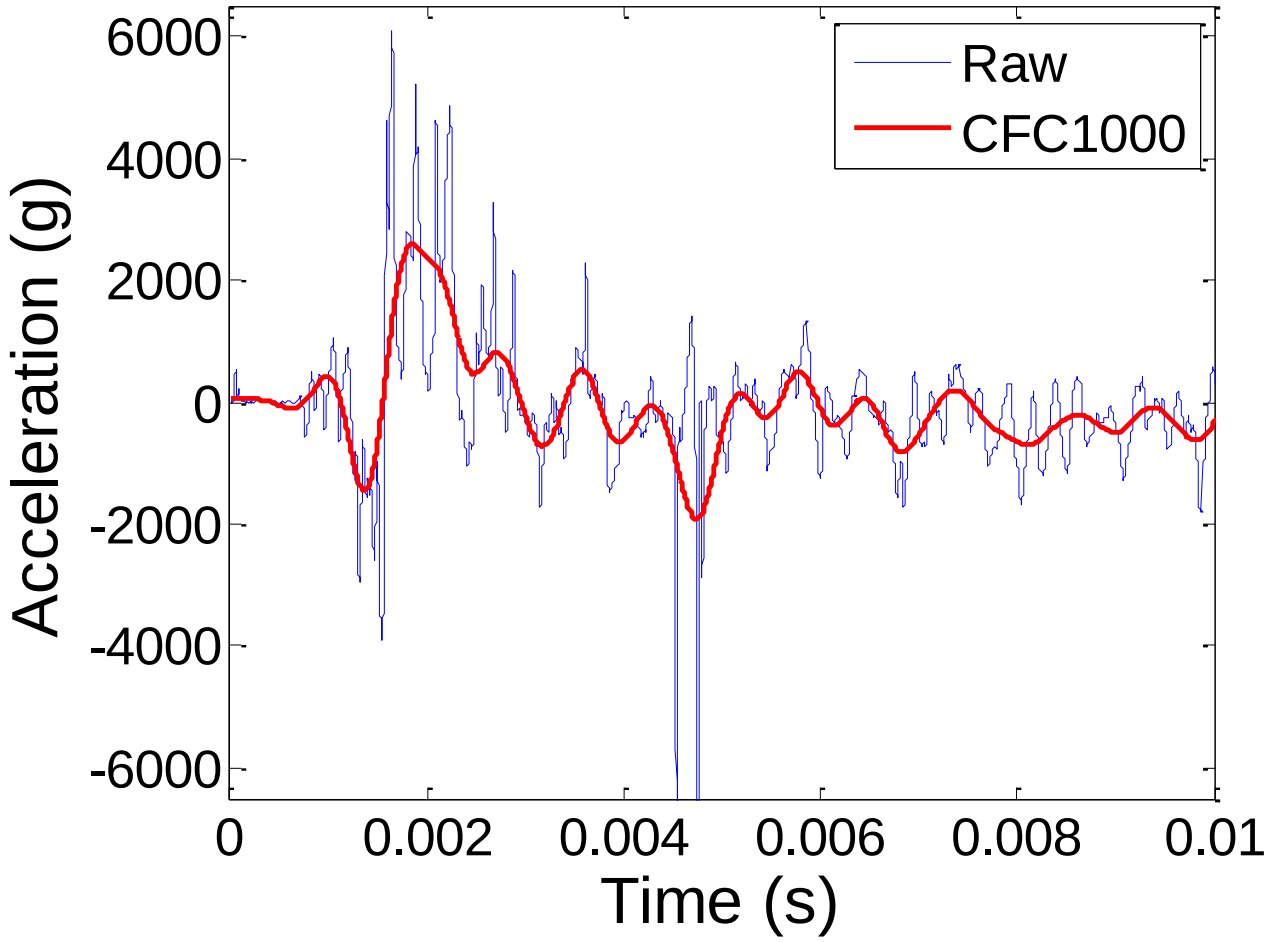
Even “good” traces can have “unexplainable” large spikes

Effects of Filtering



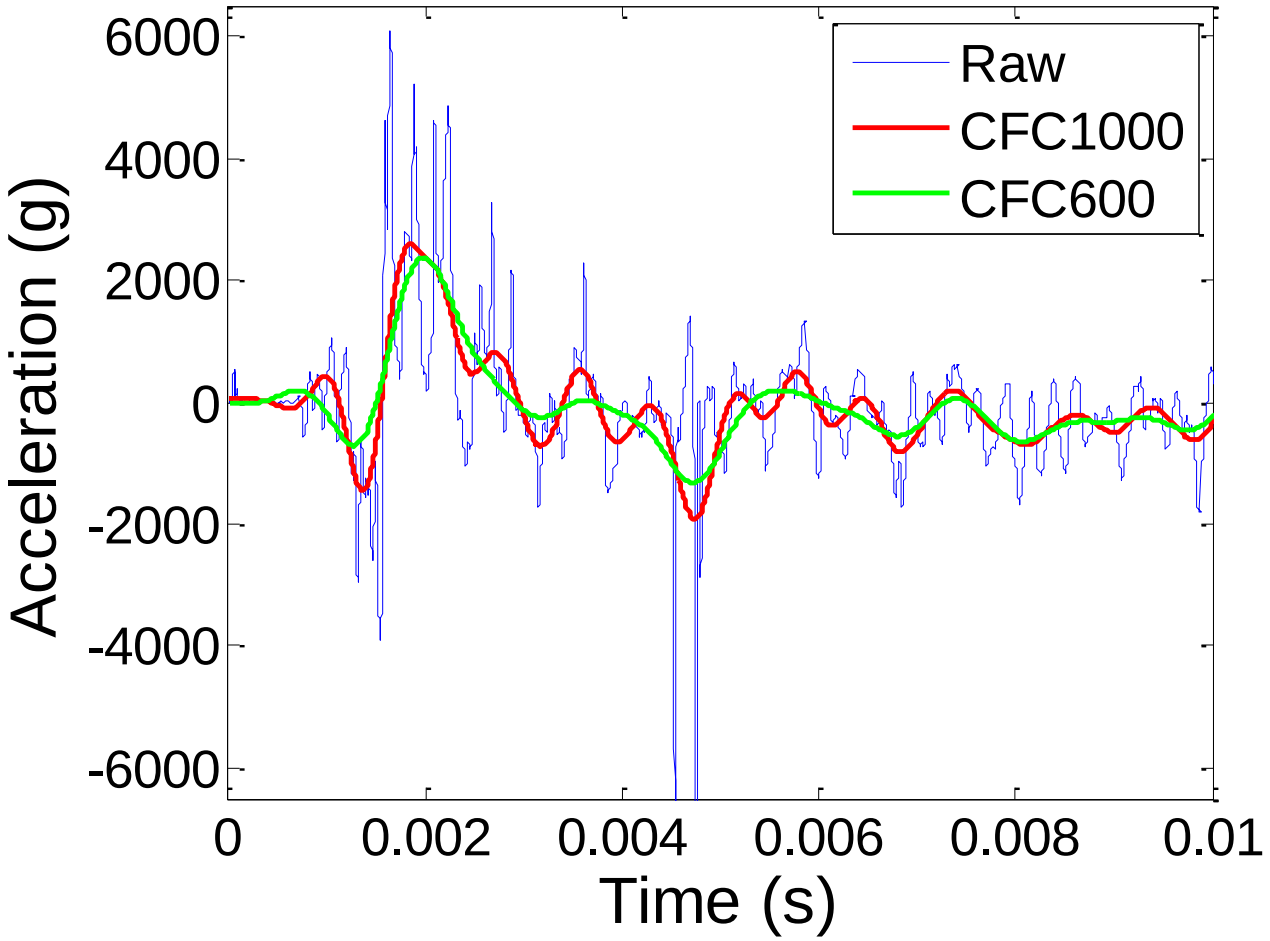
Raw floor acceleration data sampled at 1 million samples per second

Effects of Filtering



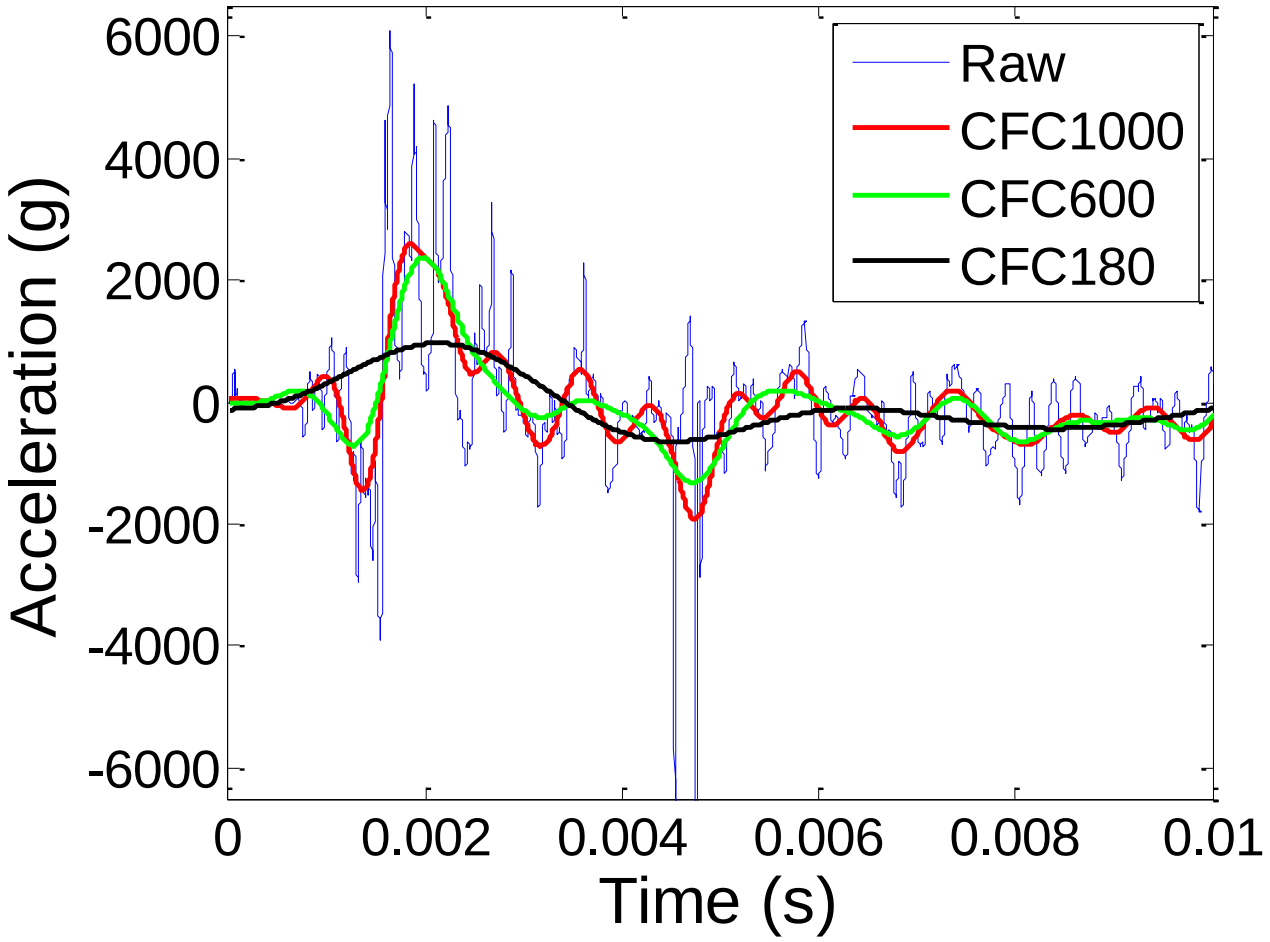
Raw data shows 6090 g Max
CFC1000 filtering 2582 g Max
(a 58% reduction in peak acceleration)

Effects of Filtering



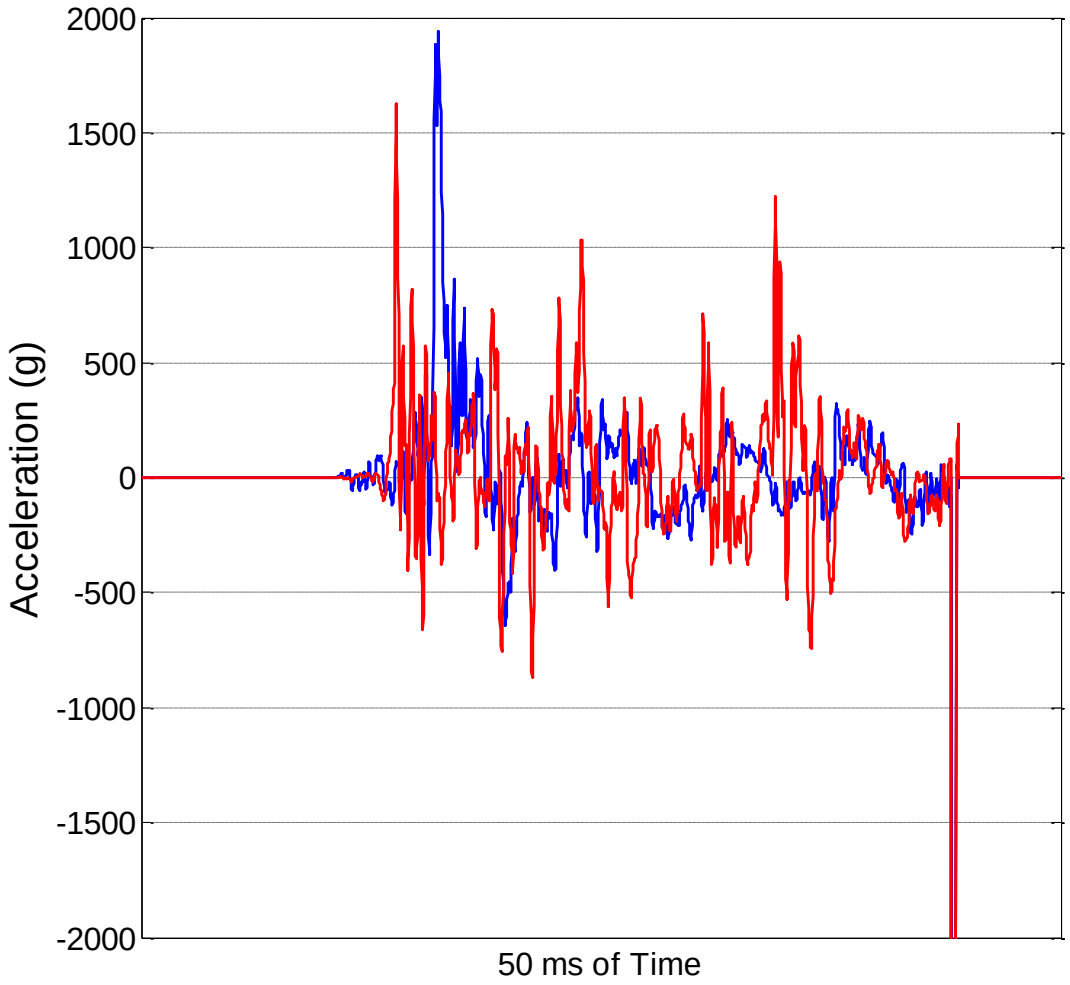
Little loss of signal from CFC 1000 to CFC 600

Effects of Filtering

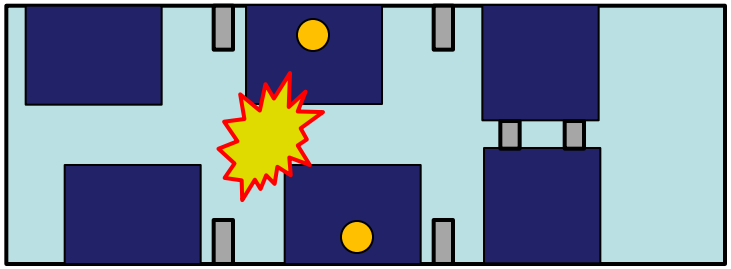


CFC 180 continues to decrease the signal amplitude

Seat Pan Accelerations

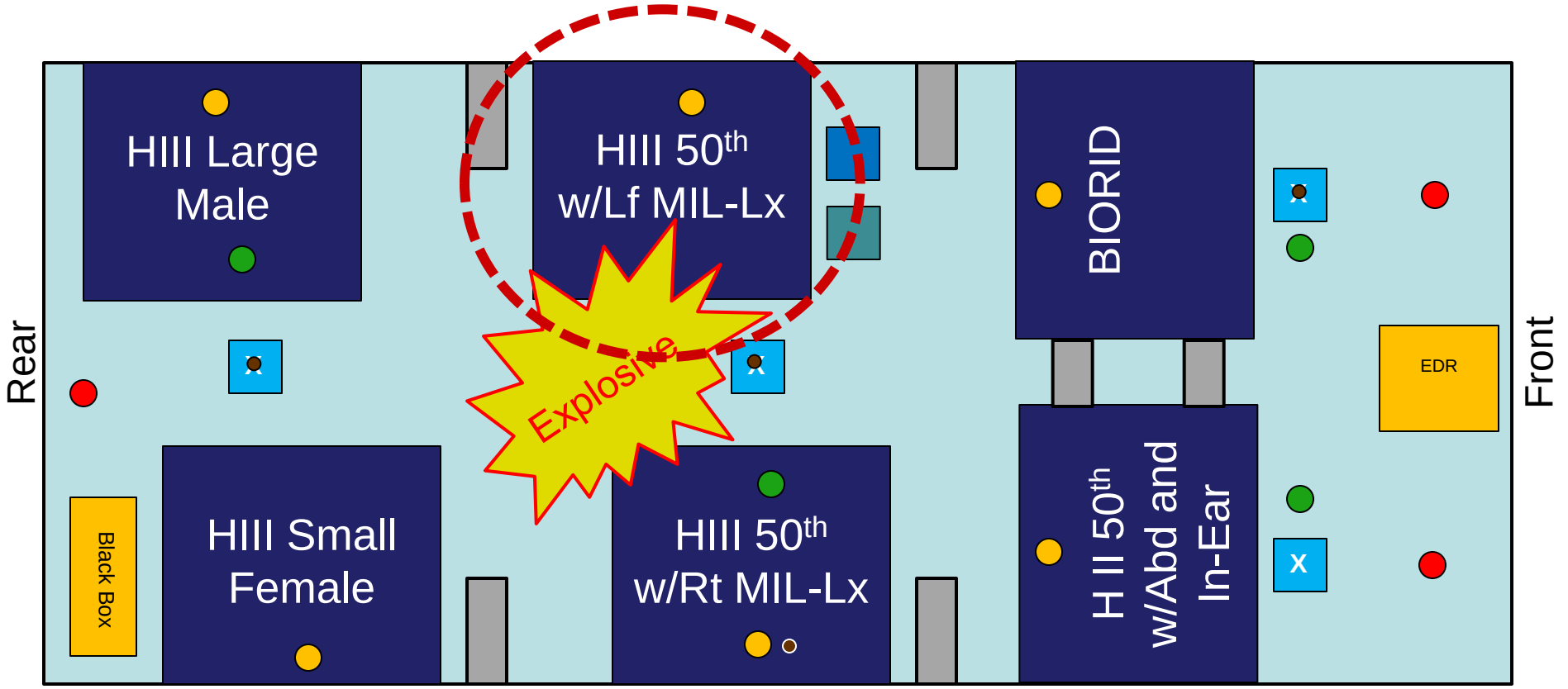


- Vertical accelerations measured by 2K g accelerometers attached to the seat pan

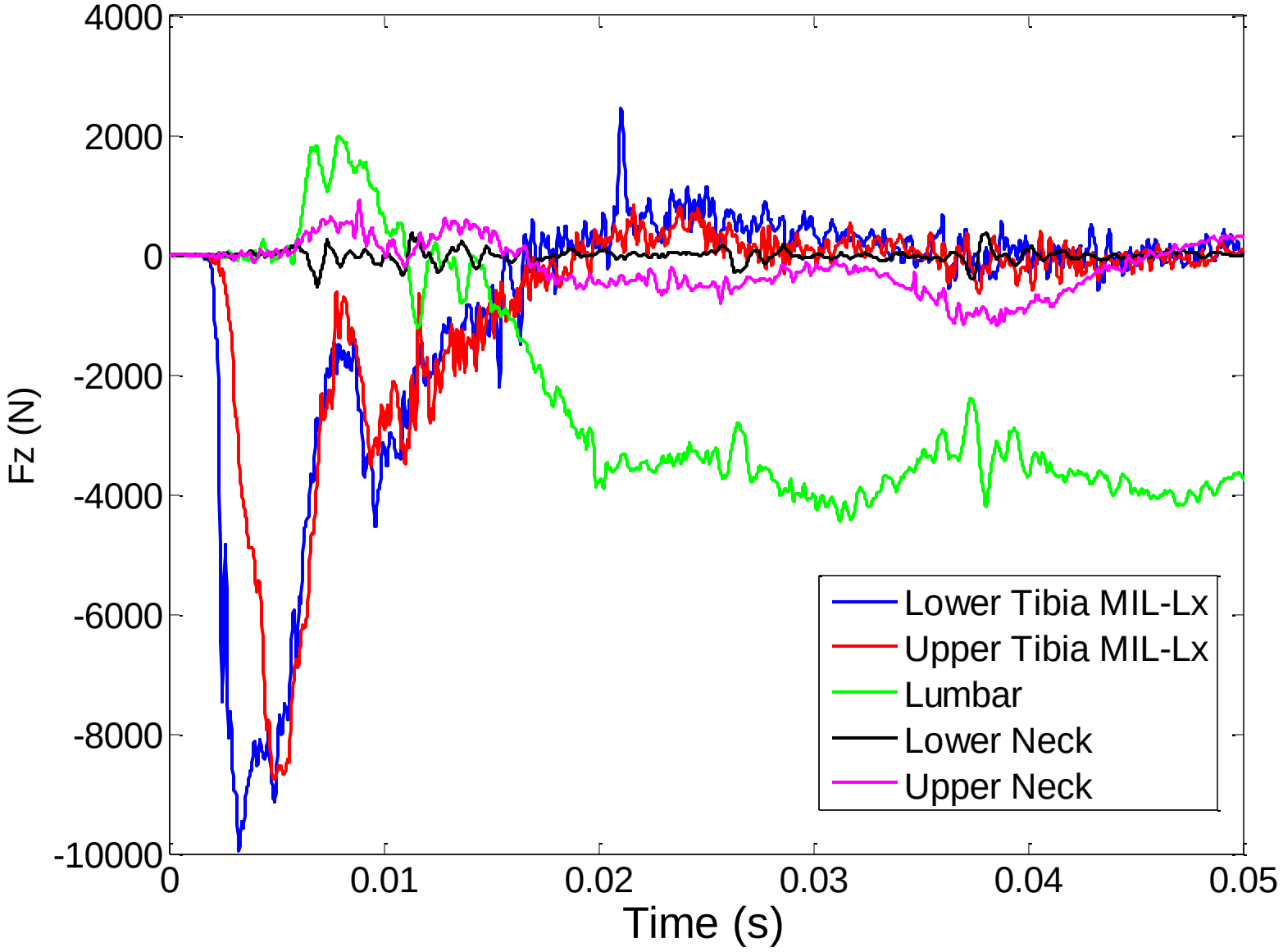


- Peak accelerations over the 50 ms of data recorded differ by > 300 Gs
- Seating positions are extremely similar
  - Proximity
  - Orientation

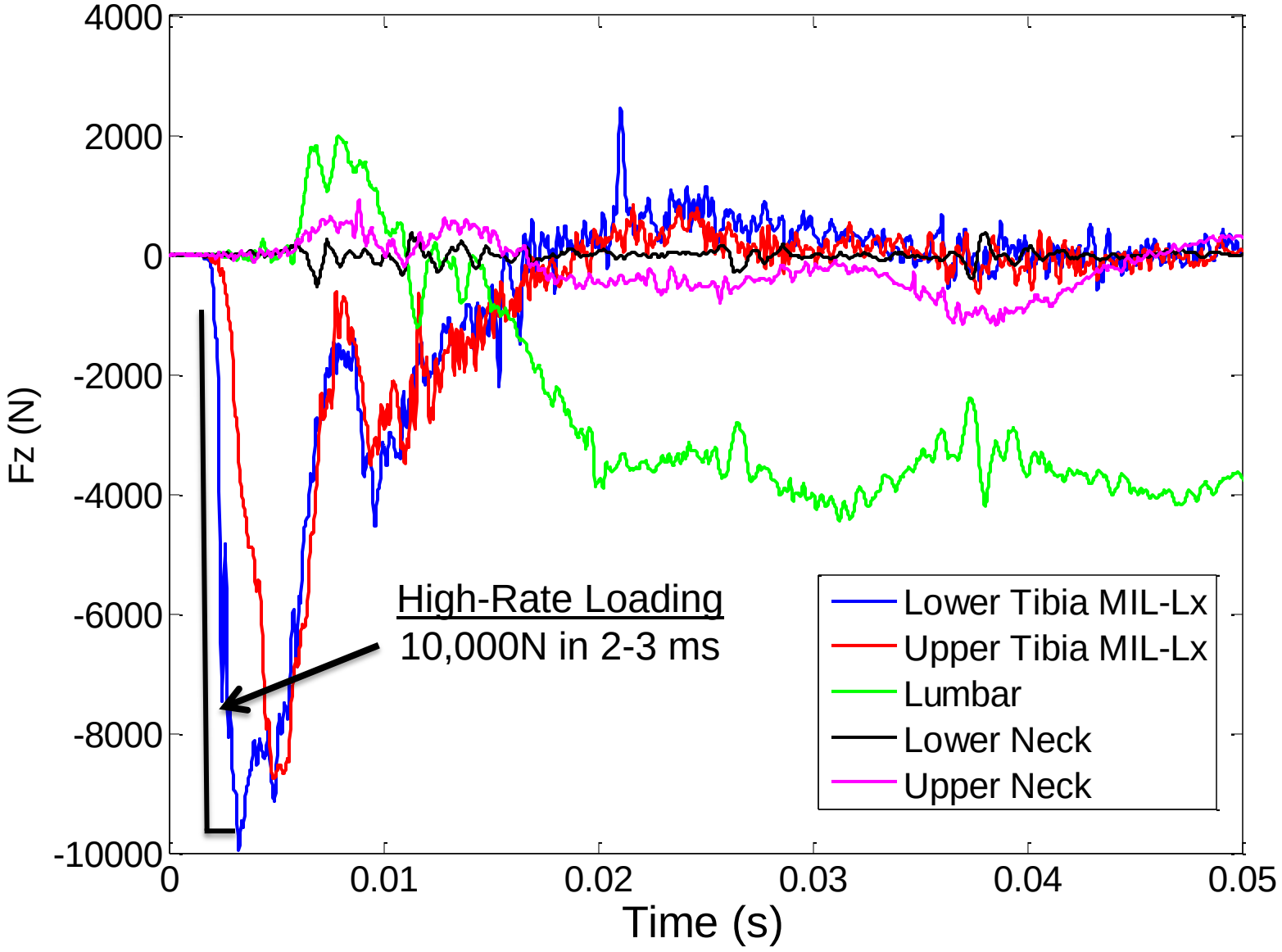
Snapshot of Occupant Loading



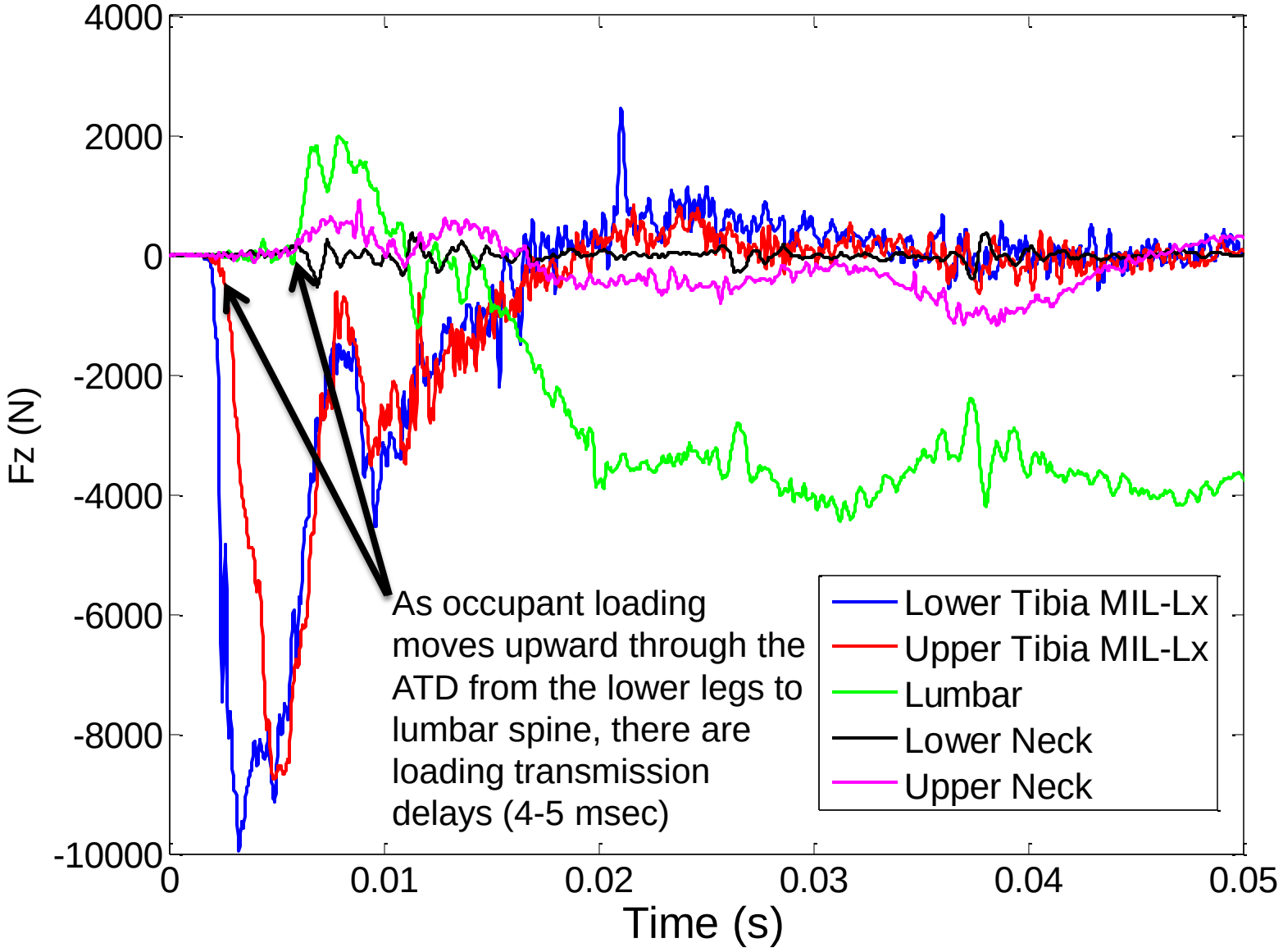
Occupant Loading: Foot to Neck



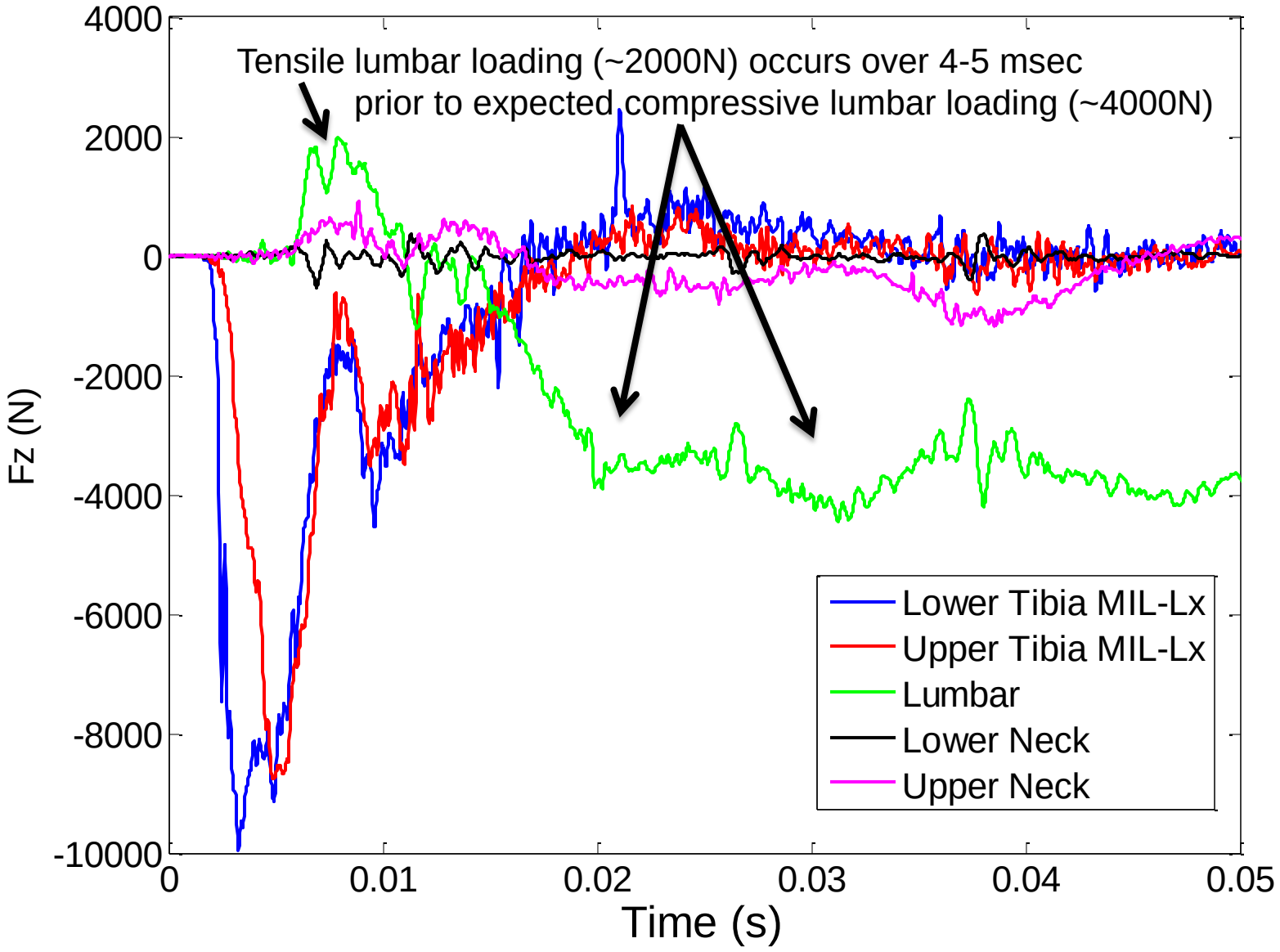
Occupant Loading: Foot to Neck



Occupant Loading: Foot to Neck



Occupant Loading: Foot to Neck



Generic Hull: Summary

- Initial characterization of structural loading and occupant response verifies that the occupant is experiencing extremely high-rate loadings due to simulated Under Body Blast blast events
- The high loading rates are particularly evident in the lower extremities
- The lumbar spine loading pattern is not readily expected due to the primarily vertical compressive nature of a simulated Under Body Blast
- The occupant loading pathways from the structure to the occupant and through the occupant require further investigation

Generic Hull: Acknowledgements

- This testing was made possible through a collaborative effort between:
  - Government:
    - TARDEC
    - USAARL
    - AMRDEC
    - USARL/SLAD
  - Academic:
    - Wayne State University
    - Virginia Tech
    - Johns Hopkins University Applied Physics Laboratory
    - University of Virginia
    - University of Michigan
  - Industry:
    - Humanetics ATD Team
    - Diversified Technical Systems (DTS)
    - Concurrent Technologies Corporation (CTC)
    - The Cosworth America Team
    - Luminys Systems Corp
    - The VICON Motion Systems Team

Questions